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AN ANALYSIS OF CONTRACTING ALTERNATIVES
FOR BASE OPERATIONS SUPPORT (BOS) FUNCTIONS

by

Priscilla A. Vanderpool

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Thesis Advisor: Dan C. Boger

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This thesis analyzes the results of the various contracting alternatives implemented by bases within different naval warfare communities. It was found that, in most cases, contracting of BOS functions did indeed result in reduced costs. Additionally, it was found that, most of the time, full base BOS contracts performed better than other contracting alternatives.

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An Analysis of Contracting Alternatives for Base Operations Support (BOS) Functions

by

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ABSTRACT

The federal government encourages contracting for the purpose of reducing operating costs. Military base operating support (BOS) functions are a prime area for such contracting. However, there exists only limited review of how effective this policy has been.

This thesis analyzes the results of the various contracting alternatives implemented by bases within different naval warfare communities. It was found that, in most cases, contracting of BOS functions did indeed result in reduced costs. Additionally, it was found that, most of the time, full base BOS contracts performed better than other contracting alternatives.

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I. INTRODUCTION AND PROBLEM STATEMENT

A. INTRODUCTION

The federal government encourages contracting for the purpose of reducing operating costs. Military base operating support (BOS) functions are a prime area for such contracting. This thesis compares the four contracting alternatives currently used by the Navy.

These four alternatives are:

1. status quo--existing methods where a contract review has never occured;

2. in-house contracting--contract review has occured and the government agency won the contract;

3. selected function contracting--a specific function or set of functions has been selected for contract review and a private sector contractor won the contract;

4. BOS contracting--the BOS functions of an entire base have been selected for contract review and a private sector contractor won the contract covering all BOS functions.

B. PROBLEM STATEMENT

Considerable military dollars are spent annually on BOS functions and on the administration of contracts for those functions. However, there has been no formal attempt to quantitatively analyze whether successful contracting methods can be applied at bases which have similar missions and support needs. This thesis provides such an analysis by comparing the relative costs among contract alternatives.

A comparison of contract performance among various military bases is conducted by using linear regression models and other econometric methods. In the regression models, explanatory variables are the amount of work measured in appropriate units (i.e., thousands of square yards, acres, linear feet); the dependent variable is the cost associated with the contracting alternative used for the work performed. Within sets of similar-mission bases, comparisons of similar functions are made among the four contracting alternatives. Each similar-mission "base set" represents a different warfare community and is comprised of two to four bases. The five base sets used are: Weapons Stations, Naval Air Stations, Submarine Bases, Naval Stations, and Naval Air Facilities. The comparison is made for the four-year period, 1984-1987.

OMB Circular A-76, the governing regulation for contracting government services, does not require that functions be considered for contracting, but leaves the decision with base commanders [Ref. 1]. The need for cost reductions often encourages base commanders to consider contracting alternatives. However, base commanders must also consider the job security of current civil service employees, control over the work being done, and the quality of the service provided. The analysis of the relative costs among contract alternatives contained in this thesis can be

used by base commanders to weigh the benefits of contracting against these concerns.

C. THESIS ORGANIZATION

In Chapter II, the governing federal regulation for contracting is described and discussed. Chapter III presents a detailed description of the data used, the regression models applied to the data, and the results for one (Weapons Stations) of the five base sets. (The remaining base sets' results are presented in Appendices A through D.) Chapter IV states the thesis conclusions regarding the relative cost efficiencies between the four contracting alternatives.

II. BACKGROUND

This chapter discusses the background of the contracting issue, as evidenced by:

1. the impact of the Office of Management and Budget's (OMB) Circular A-76 on the Federal government,
2. how the provisions of OMB Circular A-76 have been applied specifically in the U.S. Navy, and
3. the procedures required by that document.

A. IMPACT OF OMB CIRCULAR A-76

Historically, "functions", or tasks, requiring government administration have included "law enforcement, judicial activities, conduct of foreign policy, national defense, regulatory activities, tax collection, and financial administration of government." [Ref. 2] However, all of the departments and major agencies of the federal government are supported by functions which, since they do not require the direct administration of government employees, can be contracted to the private sector.

Since the late 1950's, the federal government has encouraged the contracting of such functions. OMB Circular A-76 is the federal regulation governing such contracting. This Circular originated in bulletins issued by OMB's predecessor, the Bureau of the Budget, and was revised repeatedly throughout the 1960's and 1970's. With each

revision, it has become more explicit concerning the specific procedures to be used in comparing proposed contractor performance with government performance.

It has only been during the 1980's that government agencies have recognized the need to compete against private sector contractors to retain their work by winning in-house contracts. OMB Circular A-76 establishes contracting as a means of reducing government costs. This is particularly important because of the increasing pressure to reduce the federal deficit.

There are three significant additional benefits to this policy. The first benefit is a reduction in the size of government. This reduction results from a corresponding increase in the private sector's role in providing goods and services to meet public sector needs. The second benefit is the resulting increase in government efficiency as government agencies strive to achieve their "most efficient organization" (MEO) forms. The third benefit results from new insights obtained from the private sector contractor's objectivity. These insights are reflected in the contractor's methods for budgeting, staffing, conduct of operations, and calculation of overhead costs, personnel costs, and profits.

B. OMB CIRCULAR A-76 APPLICATIONS IN THE NAVY

Navy functions which are candidates for contracting are primarily base support (BOS) functions, such as facilities maintenance, utilities, transportation services, and similar support functions. Navy functions which are exempt from the contracting process include research, test and development, maintenance of combat support capabilities, and training of military personnel. [Ref. 2]

The Naval Facilities Engineering Command (NAVFACENGCOM) is responsible for oversight of the base operating support (BOS) contracting program Navywide. In particular, data are collected and analyzed to assess the amount and quality of shore-based resources and their impact on fleet readiness. These shore-based resources are maintained through BOS functions. The oversight of these BOS functions by NAVFACENGCOM personnel entails monitoring their programming, budgeting, and execution.

C. OMB CIRCULAR A-76 CONTRACTING PROCEDURES

Base commanders may identify functions as candidates for contracting, but are not required to do so. For each function identified, a thorough review of the function is conducted to evaluate its potential for being contracted, including determining whether it is exempt from such action.

A comprehensive study of the function's cost is then conducted.

Concurrently, the government agency responsible for the function is encouraged to assess its organization and procedures, revising these as necessary, in order to achieve its' most efficient organization. Such revisions should increase productivity and will later become required elements of the contract if the government agency keeps the function in-house (i.e., the contract becomes an in-house contract as defined earlier).

The primary provision of a typical contract is the statement of work. The statement of work describes the work to be done, the standards of performance, the required outputs, and the financial penalties for contract default. Generally, the statement of work does not specify actual procedures unless dictated by military necessity, safety considerations, etc. Once the contract is awarded, whether back to the government agency or to an outside contractor, the winner must adhere strictly to the provisions of the contract.

Quality assurance (QA) is measured by the contract's standards of performance. These standards include the acceptable level of service and the percentage of time the standard is expected to be met. Although QA is the responsibility of the contractor, the government inspects

contract performance to ensure compliance. Such QA is perhaps more visible in the case of private sector contractors; however, similar inspections are also conducted on in-house contracts using normal internal review procedures.

OMB Circular A-76 also specifies requirements which promote fair competition between government agencies and the private sector contractors. Potential private sector contractors are required to include in their bids surcharges for government administration of the contract and for the costs of relocating and retraining government employees as necessary. More significantly, the contractor's bid must propose a savings of at least 10% in personnel costs and 25% in equipment costs over the in-house bid.

These requirements similarly apply if the government attempts to win back a function from a private sector contractor--the government must underbid the contractor's performance by these same differentials. OMB Circular A-76 also suggests that contracts be periodically reviewed, usually every five years, to determine whether the nature of the function has changed and whether contract compliance is being maintained.

D. OMB CIRCULAR A-76 APPLICATION RESULTS

To test whether contracting reduces costs, work and cost data for given functions were analyzed to compare the four

contracting alternatives previously defined. These functions included both BOS functions and operational functions related to the base's mission. The next chapter describes the data, the linear regression models, and the analytical results for one base set. Appendices A through D contain the analytical results for the remaining four base sets.

III. ANALYSIS

This chapter describes the data, the linear regression models, and provides an analysis of the data. Linear regression models were chosen because preliminary review of the data indicated a possible linear relationship between the work and cost data that were used. The models are illustrated using data from one of the five base sets: Weapons Stations, Naval Air Stations, Submarine Bases, Naval Stations, and Naval Air Facilities. The analytical results for the remaining four base sets are presented in Appendices A through D. All analytical results pertain to the four-year period of this study, 1984-1987. Because of mission dissimilarities, comparisons among base sets were considered unrealistic.

A. DATA

1. Sources

The primary data source for this thesis was the Real Property Maintenance Activity Execution Report (RPMA) [Ref. 3]. Naval bases annually make this report to Naval Facilities Engineering Command (NAVFACENGCOM). The purpose of the RPMA is to monitor the condition and use of shore facilities in an attempt to reduce deficiencies which may impact fleet readiness.

RPMAs include data on those management and engineering functions involved in shore facility maintenance and operation, including the maintenance and repair of real property, utilities, minor construction, and other engineering support. In particular, the RPMA provides the written justification used to set minimum funding levels for real property maintenance and provide control over backlogs of maintenance and repair work. The RPMA data used for this analysis are the amount of work units performed and the associated costs for certain BOS and operational functions.

The secondary data source for this thesis was the Detailed Inventory of the Naval Facilities Assets Data Base (NFADB). The purpose of the NFADB is to determine requirements and funding for new facilities, identify excess shore facilities, and provide a basis for real property maintenance funding. This source augmented the RPMA data when complete data were not available. The appropriateness of mixing data from these two sources was justified by comparing data values from both sources when available. The exact match of these comparisons implied that the same data was being reported to both sources.

2. <u>Selection of Variables</u>

a. General Considerations

The work and cost data for similar functions, obtained from the RPMA, were aggregated to form "functional

area variables". These functional area variables were used to represent both BOS and operational functions. The BOS functional area variables were the variables of interest for this thesis. The operational functional area variables were used only with the first "preliminary" regression model.

Because of a small number of data points, the first model was used for exploratory data analysis in determining the relationship between work performed and costs incurred. This initial model was also used to ensure that the two major assumptions of regression, normality of the residuals and equality of residual variances, were applied. The first model also provided a means to determine if any multicollinearity or autocorrelation existed among the data.

The functional area variables for the Weapons Stations (WPNSTA) base set are described in the following section. The remaining base sets' functional area variables are described in their respective appendices.

b. Weapons Stations' Functional Area Variables

The three Weapons Stations selected for this thesis were WPNSTA Seal Beach, WPNSTA Concord, and WPNSTA Yorktown. Each is a primary support base for surface ships and aircraft, providing ammunition by truck and rail, pierside, and at anchorage. Six functional area variables were considered for these bases. Because data was missing

for some years and some functional area variables, estimation was necessary. Nine missing data points were estimated, representing 6% of the data used for this base set. A description of the six functional area variables and their units of measurement is provided in Figure 1.

DESCRIPTION OF VARIABLES

COMN -- community buildings (thousands of square feet)

GRND -- improved grounds (acres)

EMERG -- emergency service work (number of calls received)

UTILS -- electricity, water and refrigeration (thousands of linear feet)

CLEAN -- pest management and custodial services (thousands of square feet)

TRASH -- garbage disposal (thousands of cubic yards)

Figure 1. Description of Weapons Stations Variables

Of these six functional area variables, only GRND and CLEAN had known contracting histories. The remaining four represent the status quo contracting alternative, never having been selected for contract review.

B. MODELS

1. General Considerations

The initial model used was a simple linear regression model of the form:

$$y = a + bx + u.$$

This model was chosen because a preliminary review of the data indicated a possible linear relationship between the dependent and independent variables. The amount of work performed in a given functional area served as the independent variable, x, while the associated annual cost was the dependent variable,y. The disturbance or error term of the equation is shown by u. The coefficient, a, is the intercept term, which indicates the value of y when x is zero. The dimensions of the coefficient, a, are dollars. The coefficient, b, is the slope coefficient, which indicates the amount of change in y when x changes by one unit. The dimensions of b are dollars per unit for the given functional area variable.

The simple linear regression model was chosen because X-Y plots of the work unit data versus cost data tended to show a linear relationship between the dependent and independent variables. The first model was applied to all work and cost data for each functional area variable used in the base set.

A second regression model, which also assumed a linear relationship between the dependent and independent variables, was applied to only those functional area variables in each base set having known contracting histories:

$$y = a + b_1x_1 + b_2x_2 + \sum_{i=1}^{3} c_iw_i + u.$$

The second model was used to compare the four contracting alternatives. It was conceptually similar to the first simple regression model, but included a second independent variable of employee costs (including total salaries and employee benefits), x2, and dummy variables representing the different contracting alternatives, w_i. The w_i is binary, and acts as a switch, taking on the value zero for contracting alternatives not used for a given functional area variable, and taking on the value one for contracting alternatives that are used.

The coefficients are a, b_i, and c_i. The a and b_1 coefficients are the same as a and b described for the first model. The b_2 coefficient is dimensionless. The c_i coefficient represents an additional cost associated with the different contracting alternatives.

2. Evaluation Measures And Expectations

As the emphasis of this thesis was on evaluating the ability of functional area variables to explain their associated costs, the primary criterion for the first model was the fit of the data to the model. This fit was measured by R-squared (R^2), the coefficient of determination. The R^2 statistic is the ratio of the explained sum of squares to the total sum of squares, or the proportion of variation in the dependent variable that is explained by the independent variable. The R^2 statistic lies between values of zero and one. The higher the R^2 statistic, the closer the data fits the regression model.

The fit of the data to the model was also measured by the significance level of the regression, p, for the null hypothesis that the functional area variables and the cost are independent (Ho: $b_i=0$, the set of explanatory variables has no influence in the determination of y). Lower values of p less than 0.10 are preferred.

Using the STATGRAPHICS software package, ordinary least squares (OLS) regressions were performed for both models. For both models, the R^2 and p statistics were used as the primary measures of the statistical fit of the data to the model.

For the second model, the t statistic was also used to measure the contribution to costs of the dummy contracting variable (Ho: $c_i=0$). The null hypothesis is rejected if the calculated t statistic is greater in absolute value than the critical t statistic value, which is obtained from t tables for a selected level of significance and the appropriate degrees of freedom. As with the overall regression significance level, p, the significance level of the t statistic, r, is ideally small to indicate the probability of observing a calculated t value greater than the critical value when the null hypothesis is correct.

It was expected that the process of contractual review would permit the realization of greater cost efficiencies. Regardless of whether the work was retained in-house or contracted out, cost decreases were anticipated for constant amounts of work performed. Further, ti was expected that BOS contracts would result in greater cost efficiencies than in-house or selected function contracts due to economies of scale.

C. WEAPONS STATIONS BASE SET RESULTS

1. Model 1

The first simple regression model was applied to the six Weapons Stations base set functional area variables (COMN, GRND, EMERG, UTILS, CLEAN, TRASH).

a. Regression Significance

Table 1 provides the R2 and p statistics for the combined and individual bases.

TABLE 1. R^2 STATISTICS AND SIGNIFICANCE LEVELS

R SQ. (R^2)	COMN	GRND	EMERG	UTILS	CLEAN	TRASH
Combined	0.09	0.08	0.69	0.42	0.02	0.44
Seal Beach	0.52	0.35	0.96	0.37	0.83	0.27
Concord	0.82	0.85	0.03	0.01	0.52	0.96
Yorktown	0.35	0.15	0.92	0.63	0.87	0.91
SIG. LEVEL	(p)					
Combined	0.36	0.39	0.00	0.02	0.66	0.02
Seal Beach	0.28	0.41	0.02	0.39	0.09	0.49
Concord	0.09	0.08	0.83	0.89	0.28	0.02
Yorktown	0.41	0.61	0.04	0.21	0.07	0.05

Table 2 explicitly identifies those regressions which reflect significant dependence ($p<=0.10$) of the functional area variables and their associated costs. Use of similar simple regression techniques could be used by base commanders to provide quantitative evaluation of the performance of other BOS functions.

TABLE 2. REGRESSIONS WITH SIGNIFICANT DEPENDENCE

	COMN	GRND	EMERG	UTILS	CLEAN	TRASH
Combined			X	X		X
Seal Be			X		X	
Concord	X	X				X
Yorktown			X		X	X

In the sections that follow, the combined bases are used to illustrate additional regression and econometric methods. Although not all of the combined variables showed significant dependence between the dependent and independent variables, the continued use of the combined variables as a complete set is maintained for illustrative purposes and for consistency's sake.

b. Residual Analysis

Figure 2 presents the component-residual plots for the combined bases for each of the six functional area variables.

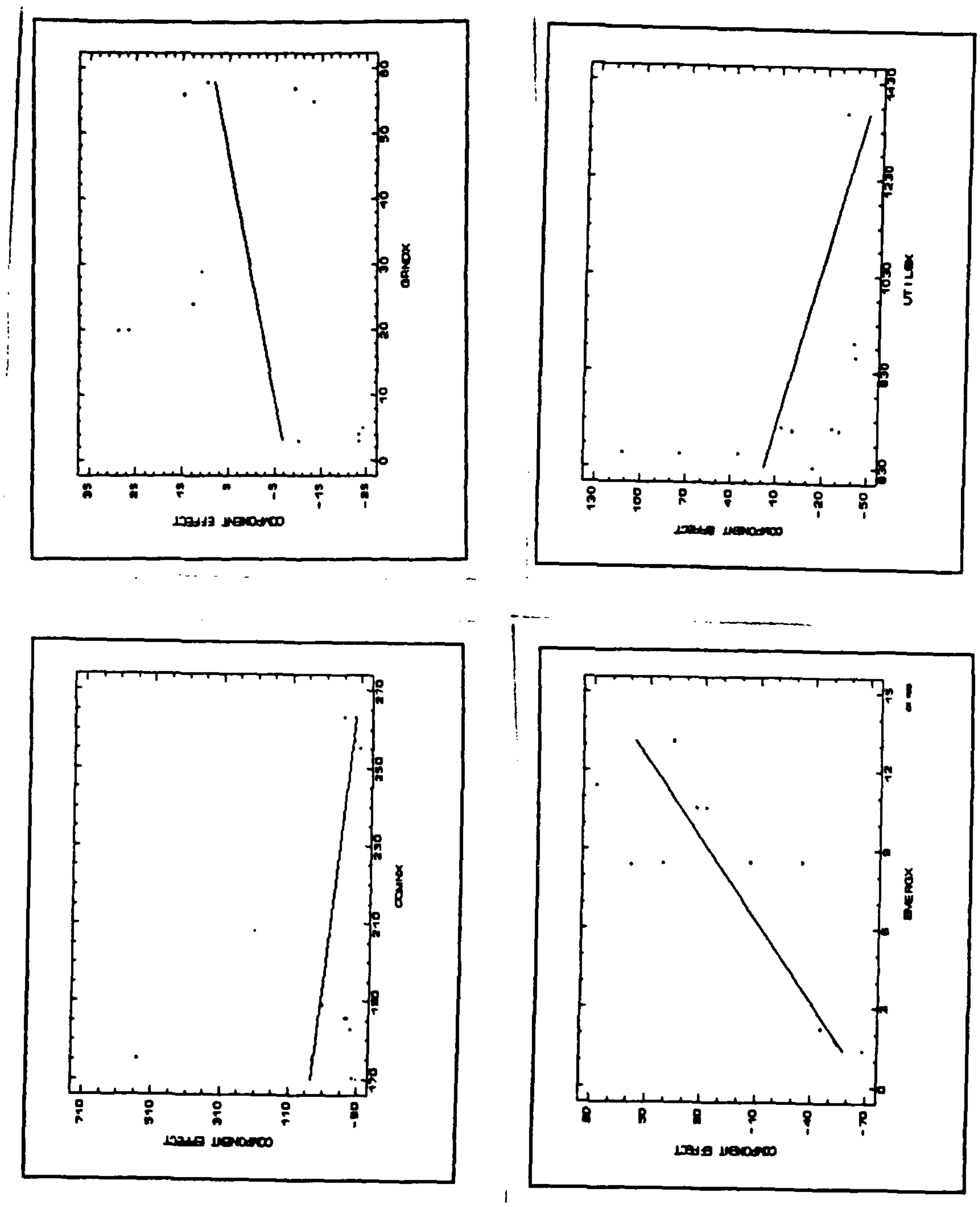

Figure 2. Component-Residual Plots

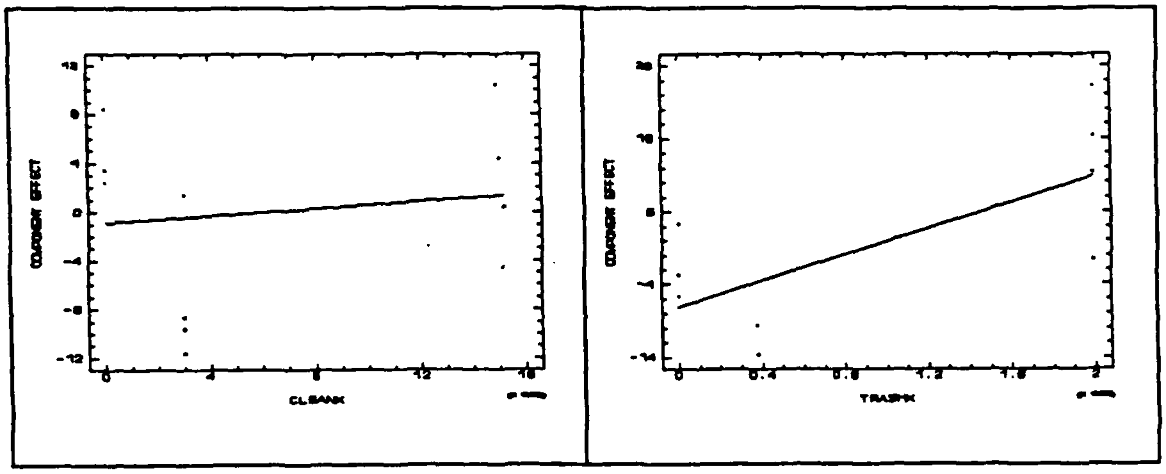

Figure 2. Component-Residual Plots (continued)

Ideally, the residuals for all bases within a given base set should be randomly distributed if the data are independent of the bases. However, all six component-residual plots show the data strongly clustered by base. This shows that the regressions were not only dependent on the work and cost data, but also on the bases for which the data were obtained. Therefore, this indicates that a third explanatory variable might be appropriate to account for the source (military base) from which the data were obtained.

c. Anticipated Modeling Concerns

(1) Data Inconsistencies. Data points were estimated when the data entries were missing or inconsistent with expected operational procedures. Such inconsistencies

were most probably the result of a realignment of costs to different cost accounts, human error, or intentional misrepresentation of the amount of work performed. Estimation was based on trends of similar data, historical sources being available in all cases. No more than 8% of all data points were estimated for each base set.

The effects of estimating data include a reduced residual variance, which results in a greater likelihood of meeting the significance criteria for R^2 and p which were previously defined. For each base set, those functional area variables for which data points were estimated were checked for artificially high significance. For the Weapon Stations base set, three of the six functional area variables were significant for the combined bases, although only one of these included estimated data. It was concluded that the estimated data points did not unduly affect the regression results.

(2) Autocorrelation. Because the first model used only one explanatory variable, it was expected that autocorrelation might occur as a result of unused or unavailable explanatory variables. Further, autocorrelation could have resulted from specification error in the model or measurement error of the dependent variable. The latter was of particular concern due to the inconsistencies previously noted in the data.

The analysis of variance tables produced by STATGRAPHICS provided Durbin-Watson statistics. Durbin-Watson statistics are used to test the null hypothesis of no serial correlation. Upper and lower critical values, d_u and d_l, are provided in tables for selected levels of significance, number of observations, and degrees of freedom. The null hypothesis is rejected if the Durbin-Watson statistic is less than d_l and accepted if greater than d_u. The test is inconclusive if the Durbin-Watson statistic falls between these critical values. Using the Savin-White tables of Durbin-Watson values [Ref. 4], the Durbin-Watson test was applied to each of the combined variables within each base set. Where autocorrelation was found to exist, the data were transformed to eliminate the autocorrelation and the Durbin-Watson test run again to verify the absence of autocorrelation after transformation.

For the Weapons Stations base set, the functional area variables for the combined bases were tested for autocorrelation, and their Durbin-Watson (D-W) statistics were computed. With 12 observations, 2 degrees of freedom, and 1% significance, the values for d_l and d_u were .569 and 1.274, respectively. Of the six variables, one, COMN, revealed no autocorrelation and the other five fell within the inconclusive region.

(3) Heteroscedasticity. The potential for nonconstant variance was considered due to the cross-section data used. A simple preliminary check was made by examining the residual plots for any "horn-shaped" or "fan-shaped" distributions. Because none of the variables in any of the five base sets indicated this type of distribution, no formal test was performed.

(4) Multicollinearity. Multicollinearity occurred rarely as a result of constant values reported for the explanatory variable over the entire four-year period. In these few instances, the STATGRAPHICS software reported the existence of collinearity and eliminated that variable from the regression model. Collinearity was absent from the six Weapons Stations functional area variables.

(5) Test For Structural Change. Using the Chow test, the data were also tested for structural change of slopes and intercepts over the four year period. The Chow test is a specialized application of the F-test that identifies whether significantly different regression coefficients are calculated for different data samples in the same theoretical model. F statistics were computed and compared to F distribution table values for the appropriate degrees of freedom parameters [Ref. 4].

In all cases where structural change was indicated, X-Y plots of the data were reviewed to verify

these results. As with previous modeling problems, the structural change was believed to result from the data inconsistencies discussed earlier, most notably changes in the base's interpretation of data reporting requirements.

When the Chow test was applied to the Weapons Stations base set, the F(.05) table value was 4.46 for 2 and 8 degrees of freedom. Five of the six F values (COMN, GRND, EMERG, CLEAN, TRASH) fell below this table value; therefore, the hypothesis that no structural change occurred could not be rejected for those five functional area variables. The calculated F value for the UTILS functional area variable was above the 4.46 table value, indicating structural change.

(6) Summation of Modeling Tests. Table 3 summarizes the results obtained from the hypothesis tests discussed in sections (2) and (5) above.

2. Model 2

As previously noted, Model 2 is conceptually similar to Model 1. Model 2 differs in three ways:

1. it is applied to only those variables with known contracting histories;
2. it includes a second explanatory variable representing employee costs; and
3. dummy variables are used to reflect the different contracting alternatives in use within a given base set.

TABLE 3. SUMMATION OF MODELING TESTS

VARIABLE	TESTS	
	AUTOCORRELATION	STRUCTURAL CHANGE
COMN	Accept Ho	Accept Ho
GRND	Inconclusive	Accept Ho
EMERG	Inconclusive	Accept Ho
UTILS	Inconclusive	Reject Ho
CLEAN	Inconclusive	Accept Ho
TRASH	Inconclusive	Accept Ho

a. **Application of Model 2**

Table 4 presents the estimated coefficients for Model 2 for the Weapons Stations' functional area variables. These coefficients are reported for Model 2 only, because Model 2 addresses the problem statement of this thesis--the measurement of the relative cost efficiencies of the different contracting alternatives. In contrast, Model 1 is merely a simple regression model and does not provide any significant information other than fitting a line to the data.

TABLE 4. MODEL 2 REGRESSION COEFFICIENTS

VARIABLE	a-hat	b_1-hat	b_2-hat	c_i-hat
GRND (i=1)	2872.56	183.95	0.02	31150.92
CLEAN(i=2)	9359.69	0.09	0.00	14676.04

i= 1 = in-house contract
2 = selected function contract

b. Data Considerations

For the six Weapons Stations' functional area variables only two, GRND and CLEAN, had known contracting histories. Of the three Weapons Stations, only WPNSTA Concord did not use the status quo contracting alternative. Concord had won the GRND (grounds maintenance) contract in-house and a private sector contractor had won the CLEAN (custodial services) contract as a selected function contract.

The amount of acreage covered by Concord's in-house GRND contract fell between the amounts of acreage at the other two bases. This is advantageous for comparing the in-house contracting alternative at Concord with the status quo contracting alternative at Seal Beach and Yorktown.

In contrast, the amount of area covered by Concord's selection function CLEAN contract was significantly less than the area covered by the other two bases. This, and the fact that Concord's contract was confined to pest management services only, explains why Concord incurred relatively small costs for this functional area.

An unexplainable anomaly was found in the cost of WPNSTA Concord's "housekeeping tasks", as measured by the CLEAN and TRASH functional areas. Although Concord supported a larger population and had higher employee costs than the other Weapons Stations, it performed these tasks at less cost.

c. **Regression Significance**

Table 5 presents the R^2 statistics; the regression significance level, p, measuring the fit of the model; and the t statistics with their respective significance levels, r, for the GRND and CLEAN models. As described earlier, the t values were used to measure the influence of the dummy contracting variables on costs. The t values reported in Table 5 are both significant at a level of significance of .05 for 8 degrees of freedom.

TABLE 5. REGRESSION STATISTICS AND SIGNIFICANCE LEVELS

VARIABLE	R^2	p	t	r
GRND	0.77	0.006	4.186	0.003
CLEAN	0.53	0.095	2.265	0.053

d. Cost Trends

For both the CLEAN and GRND functional area variables, increases in the amount of work performed caused an expected rise in costs, with CLEAN showing a significant increase. However, increases in employment costs resulted in no change in overall costs for either CLEAN or GRND at a significant level. This may have been due to the efficiencies of the contract.

e. Effects of Contracting Alternatives

Both the GRND and CLEAN models experienced increased costs for the dummy variables at extremely high significance levels. This indicates that the contracts themselves resulted in increased costs. This counterintuitive result does not adequately explain the relationship between contracting and costs. A better

description of this relationship is possible by examining the data reported.

(1) The GRND Data. WPNSTA Seal Beach maintained the GRND function using a status quo contracting alternative. This base reported unusually low work units performed for the variable GRND (3 to 5 acres out of a total land area of nearly 14000 acres), and costs which dropped from $21,000 to $8,000 after the first year of the study. While this data may be accurate, it provides such extreme outliers as to question whether the data truly reflected the actual work being performed, as well as the true costs incurred.

One obvious reason for incorrect data is that errors may have occurred in properly recording the data in the required format. A second possible reason is the intentional misrepresentation (i.e., "gundecking") of the data by those who are assigned the tedious task of reporting it. A third reason, of more serious consequence, is that the reporting of extreme data may indicate a deliberate attempt to avoid a possible contract review of functions that might otherwise be of sufficient magnitude and cost.

WPNSTA Yorktown also maintained the GRND function at the status quo. However, unlike WPNSTA Seal Beach, costs more than doubled during the four-year period while the amount of work performed increased by only 5%.

In contrast to both of the above bases, WPNSTA Concord had won the GRND contract in-house. While the amount of work performed increased only slightly, costs decreased by a total of $16,000 during the four-year period.

It is believed that the dummy variable representing contracting reflected significantly increasing costs due to the fact that Yorktown performed nearly twice as much work as Concord at an average cost of 40% less than Concord. In essence, the cost-reducing effect of Concord's contract is lost in the sheer volume of Yorktown's work. The effect of Concord's contract is evident in the trend of decreasing costs at concord versus the trend of increasing costs at Yorktown. This implies that the conclusion that contracts increase costs reached from Model 2 is incorrect. This may be due to incorrect data, as discussed previously, or because the volume of work performed by one base simply overshadows the amount of work performed by another base.

(2) The CLEAN Data. For the variable CLEAN, Seal Beach reported a cost increase over the four year period of 50%, although work output rose by only 0.13%. Yorktown's costs decreased 52% over the first three years, then rose 36% during the fourth year, while work output only increased by 1.3% over the four-year period.

WPNSTA Concord, under its selected function CLEAN contract, performed considerably less work than the other bases, with output increased by only 11 work units and costs decreased by a total of $6,000. As with the GRND variable, the disparity in the volume of work performed between Concord and the other Weapons Stations caused an overall increase in costs for the combined bases. However, the performance of the individual bases shows that contracting reduced costs during the same time period in which not contracting increased costs.

D. REMAINING FOUR BASE SETS

The comparison results for the remaining four base sets (Naval Air Stations, Submarine Bases, Naval Stations, and Naval Air Facilities) are contained in Appendices A through D. The following chapter summarizes the analysis results for all five base sets.

IV. CONCLUSIONS

A. SUMMARY STATISTICS

Seven of the 13 bases (54%) included in this thesis used some form of contracting. Contracts were awarded on 38 of the 46 functions (83%) studied. Twelve of these 38 functions (32%) were "well fit" by the regression models. These regression models were used to explore the relationship among the amount of work performed, the contract alternatives used, and the associated costs. The twelve functions determined to have good fits to the regression models are used as the basis for the summarized results which follow.

B. RESULTS BY CONTRACT TYPE

In-house contracting was compared to the status quo contracting alternative for two of the twelve functions. In-house contracts were more cost-efficient for both (100%) of these comparisons.

In-house and BOS contracting were compared for six of the twelve functions. BOS contracts were more cost-efficient for four (67%) of these comparisons.

Selected function contracting was compared to the status quo for 3 of the twelve functions. Selected function

contracts were more cost-efficient for two of the three (67%) comparisons.

BOS contracting was more cost-efficient than the status quo contracting alternative in the one case (100%) where this comparison was made.

Table 6 summarizes the comparisons made between contracting alternatives. The table entries reflect the percentage of comparisons in which the contracting alternative on the vertical axis performed more efficiently than the alternative on the horizontal axis.

TABLE 6. SUMMARIZATION OF CONTRACTING COMPARISONS

	STATUS QUO	IN-HOUSE	SELECTED FUNCTION	BOS
STATUS QUO	-	0%	33%	0%
IN-HOUSE	100%	-	-	33%
SELECTED FUNCTION	67%	-	-	-
BOS	100%	67%	-	-

Based on the above comparisons, the following cost-efficiency hierarchy was inferred for the four contracting alternatives:

(1) BOS

(2) In-house

(3) Selected function

(4) Status quo

Selected function contracting was not placed higher in the hierarchy because it did not perform as well as in-house and BOS contracting when compared with the status quo.

This hierarchy was intuitively expected; and validates the general contracting policies of OMB Circular A-76 and the BOS contracting programs of NAVFACENGCOM. The above one-to-one comparisons and hierarchy answer the problem statement presented at the beginning of this thesis by giving base commanders quantitative information on the relationships between work performed, costs, and contract types.

C. FINAL REMARKS AND RECOMMENDATIONS

As discussed in this thesis, a number of factors disrupted a smooth comparison between bases. These included disparities in work output, incorrectly recorded data, and suspected intentionally incorrect data. In spite of these deficiencies, however, it is felt that this thesis provides greater justification for the additional use of contracting. If similar quantitative analysis is performed regularly, more base commanders might be encouraged to perform

contracting, resulting in significant reductions in base operating support costs. Additionally, it may be possible to attain a more efficient organization either through the revitalization of existing in-house operations or through the application of new methodologies and organizational designs as proposed by outside contractors. Finally, with the efficiencies realized through the contracting process, support of the Fleet through shore establishment readiness can only be improved.

APPENDIX A. NAVAL AIR STATIONS RESULTS

Using the procedures described in Chapter III of this thesis, the following results were obtained for the Naval Air Stations base set.

A. Naval Air Stations' Functional Area Variables

The four Naval Air Stations selected for this thesis were NAS Cecil Field, NAS Oceana, NAS Miramar, and NAS Lemoore. Each is a primary support base for carrier air wings and serves as a homeport for a variety of aircraft including the F-14, S-3, A-7, and F-18. Seven functional areas variables were considered for these bases. A description of the seven functional area variables is provided in Figure A-1.

Of these seven functional area variables, only GRND, UTILS and STOR had known contracting histories. The remaining four represent the status quo contracting alternative, having never been selected for contract review.

B. Model Results

1. Model 1

The first simple regression model was applied to the seven Naval Air Stations base set functional area variables. The data from Miramar and Lemoore were analyzed separately

from the Oceana and Cecil Field data; this was due to how the data originally became available for study.

DESCRIPTION OF FUNCTIONAL AREA VARIABLES

KSF --	aviation operations, maintenance and production buildings (thousands of square feet)
RUNWAY--	airfield runways and other airfield pavements (thousands of square yards)
UTILS --	heating, water, sewage, and air conditioning (thousands of linear feet)
STOR --	supply storage (thousands of square feet)
OTHFAC--	navigation and traffic aids, land operations and aircraft maintenance/production facilities, other than buildings (per each item)
PAVEMT--	roads and streets, other surfaced areas, sidewalks (thousands of square yards)
GRND --	improved, semi-improved and unimproved grounds (acres)

Figure A-1. Description of Naval Air Stations Functional Area Variables

a. Regression Significance

Table A-1 provides the R^2 statistics for the combined Miramar and Lemoore bases. Table A-2 provides the R^2 statistics for the combined Oceana and Cecil Field bases. Both tables explicitly identify those regressions which reflect dependence at a level of significance of $p<=0.10$.

TABLE A-1. R^2 STATISTICS AND SIGNIFICANCE LEVELS MIRAMAR AND LEMOORE

VARIABLE	R SQ.	SIG. LEVEL
RUN	0.47	0.06
UTILS	0.79	0.00
STOR	0.56	0.03
GRND	0.40	0.09

TABLE A-2. R^2 STATISTICS AND SIGNIFICANCE LEVELS OCEANA AND CECIL FIELD

VARIABLE	R SQ.	SIG. LEVEL
PAVEMT	0.38	0.11
GRND	0.77	0.004

b. Residual Analysis

The seven component-residual plots showed the data clustered by base. As was concluded in Chapter III, this indicated that the regressions were not only dependent on the work and cost data, but also on the bases for which the data were obtained.

c. Tests For Anticipated Modeling Concerns

(1) Data Inconsistencies. Data entries were estimated for 24 missing data points (less than 4% of all

data points). Those functional area variables for which data points were estimated were checked for artificially high significance. Because of the paired sub-sets used in the Naval Air Station base set, comparative assessment could not be made, although the estimated data did not exceed 4%.

(2) Autocorrelation. For the Naval Air Stations base set, the functional area variables for the combined bases were tested for autocorrelation by computing and their Durbin-Watson (D-W) statistics. With 16 observations, 2 degrees of freedom, and 1% significance, the values for d_l and d_u were .737 and 1.252, respectively. One functional area variable's D-W statistic yielded a value less than d_l and greater than zero, thus indicating autocorrelation. After transforming the data, the autocorrelation was resolved. Of the other functional area variables, five statistics did not show autocorrelation; while one statistics fell within the inconclusive region.

(3) Heteroscedasticity. The clustering of data by base and the overall spread of observations did not indicate that heteroscedasticity was likely; therefore, no formal tests were performed.

(4) Multicollinearity. Multicollinearity was absent from the seven Naval Air Stations functional area variables.

(5) Test For Structural Change. When the Chow test was applied to the Naval Air Stations base set, the F(.05) table value was 4.10 for 2 and 10 degrees of freedom. The calculated values for four functional area variables fell below this table value, indicating no structural change. For three functional area variables, RUNWAY, UTILS, and GRND, the calculated values were greater than the table value, indicating structural change.

(6) Summation of Modeling Tests. Table A-3 summarizes the results obtained from the hypothesis tests discussed in sections (2) and (5) above.

TABLE A-3. SUMMATION OF MODELING TESTS

VARIABLE	TESTS	
	AUTOCORRELATION	STRUCTURAL CHANGE
KSF	Accept Ho	Accept Ho
RUNWAY	Inconclusive	Reject Ho
UTILS	Accept Ho	Reject Ho
STOR	Accept Ho	Accept Ho
OTHFAC	Accept Ho	Accept Ho
PAVEMT	Accept Ho	Accept Ho
GRND	Reject Ho	Reject Ho

2. Model 2

a. Data Considerations

For the seven Naval Air Stations' functional area variables only GRND, UTILS, and STOR had known contracting histories. Because STOR did not yield significant results from the second model, it was omitted from further analysis.

Of the four Naval Air Stations, NAS Cecil Field and NAS Oceana did not use the status quo contracting alternative. Oceana had won the GRND contract in-house and a private sector contractor had won the GRND and UTILS contracts at Cecil Field as selected function contracts.

b. Application of Model 2.

Table A-4 presents the estimated coefficients for Model 2 for the Naval Air Stations' functional area variables.

TABLE A-4. MODEL 2 REGRESSION COEFFICIENTS

VARIABLE	a-hat	b_1-hat	b_2-hat	c_i-hat
GRND (i=1,2)	4.66E5	-13.11	-0.06	6.93E5, 5.11E5
UTILS (i=2)	1.09E7	-6294.03	0.75	-2.63E6

i= 1= in-house contract
2= selected function contract

c. Regression Significance

Table A-5 presents the R^2 statistic; the regression significance, p; and the t statistic with its significance level, r; for those functional area variables which had significant results for Model 2.

TABLE A-5. REGRESSION STATISTICS AND SIGNIFICANCE LEVELS

VARIABLE	R^2	p	t_i	r
GRND(i=1,2)	0.87	0.00	2.799	0.02
			1.736	0.11
UTILS(i=2)	0.83	0.00	-2.092	0.06

i= 1= in-house contract
   2= selected function contract

d. Effects of Contracting Alternatives

(1) The GRND Data. Both bases which had GRND contracts experienced a rise in costs as indicated by the dummy variables for contracting. The amount of acreage covered by Oceana's in-house GRND contract fell among the amounts of acreage at the other bases. This is advantageous for comparing the in-house contracting alternative at Oceana with the status quo contracting alternative at Miramar and Lemoore and the selected function contract at Cecil Field.

Oceana was more efficient than Miramar by 72%, however, Cecil Field was more efficient than Oceana by 50%. Although Lemoore was more efficient than Oceana by 44%, Cecil Field was still more efficient than Lemoore by nearly 11%. Both Oceana and Cecil Field yielded significant (p=.02 and p=.11, respectively) regressions from the second model. It is believed that the less significant results for Cecil Field's selected function contract may be due to the presence of a second contract in the set.

(2) The UTILS Data. For Cecil Field, Oceana and Miramar, increased amounts of work required increased costs. However, NAS Lemoore was performing nearly 40% more work than Cecil Field at approximately 17% less cost. In spite of the outlier effect of the Lemoore data, the trend for the majority of bases was reflected in a significant (p=.06) fit to the model. This may have been due to Cecil Field's selected function contract balancing against the Lemoore data.

APPENDIX B. SUBMARINE BASES RESULTS

Using the procedures described in Chapter III of this thesis, the following results were obtained for the Submarine Bases base set.

A. SUBMARINE BASES' FUNCTIONAL AREA VARIABLES

The two Submarine Bases selected for this thesis were SUBASE Bangor and SUBASE San Diego. Each is a primary support base for SSN attack submarines, while Bangor is also homeport to the Trident ballistic missile SSBN platform. Six functional area variables were considered for these bases. A description of the six functional area variables is provided in Figure B-1.

DESCRIPTION OF FUNCTIONAL AREA VARIABLES

PIER -- piers (in linear feet)

OPER -- buildings related to operational functions, including training, maintenance, ammunition storage (thousands of square feet)

SUPP -- administrative and community buildings (thousands of square feet)

TROOP -- BEQs/BOQs and galley facilities (thousands of square feet)

PAVE -- roads, streets and other pavements (square yards)

GRNDS -- improved grounds (acres)

Figure B-1. Description of Submarine Bases Functional area variables

Of these six functional area variables, all had known contracting histories, as SUBASE Bangor was under a full-base BOS contract.

B. Model Results

1. Model 1

The first simple regression model was applied to the six Submarine Base base set functional area variables.

a. Regression Significance

Table B-1 provides the R2 statistics for the combined bases. The table explicitly identifies those regressions which reflect dependence at a level of significance of $p \leq 0.10$.

TABLE B-1. R2 STATISTICS AND SIGNIFICANCE LEVELS

VARIABLE	R SQ.	SIG. LEVEL(p)
GRNDS	0.77	0.06
TROOP	0.47	0.004

b. Residual Analysis

The six component-residual plots showed the data clustered by base. As was concluded in Chapter III, this indicated that the regressions were not only dependent on

the work and cost data, but also on the bases for which the data were obtained.

c. Tests For Anticipated Modeling Concerns

(1) Data Inconsistencies. Data entries were estimated for 14 missing data points (7% of all data points). Those functional area variables for which data points were estimated were checked for artificially high significance. Although all of the Submarine Base functional area variables were estimated for one year of one base, three of the six functional area variables showed significant R^2 statistics. This may indicate a possible relationship between data estimation and regression significance.

(2) Autocorrelation. The functional area variables for the combined bases were also tested for autocorrelation by computing their Durbin-Watson (D-W) statistics. With 14 observations, 2 degrees of freedom, and 1% significance, the values for d_l and d_u were .660 and 1.254, respectively. Autocorrelation was not found to exist for four functional area variables. Of the other functional area variables, two statistics fell within the inconclusive region.

(3) Heteroscedasticity. The clustering of data by base and the overall spread of observations did not

indicate that heteroscedasticity was likely; therefore, no formal tests were performed.

(4) Multicollinearity. Multicollinearity was absent from the six Submarine Base functional area variables.

(5) Test For Structural Change. When the Chow test was applied to the Submarine Bases base set, the F(.05) table value was 4.46 for 2 and 8 degrees of freedom. The calculated values for three functional area variables fell below this table value, indicating no structural change. For three functional area variables, PIER, TROOP, and GRNDS, the calculated values were greater than the table value, indicating structural change.

(6) Summation of Modeling Tests. Table B-2 summarizes the results obtained from the hypothesis tests discussed in sections (2) and (5) above.

2. Model 2

a. Data Considerations

For the six Submarine Base functional area variables, all had known contracting histories, due to Bangor's BOS contract. SUBASE San Diego used the status quo contracting alternative.

TABLE B-2. SUMMATION OF MODELING TESTS

VARIABLE	TESTS	
	AUTOCORRELATION	STRUCTURAL CHANGE
PIER	Inconclusive	Reject Ho
OPER	Accept Ho	Accept Ho
SUPP	Accept Ho	Accept Ho
TROOP	Accept Ho	Reject Ho
PAVE	Inconclusive	Accept Ho
GRNDS	Accept Ho	Reject Ho

b. Application of Model 2

Table B-3 presents the estimated coefficients for Model 2 for the Submarine Bases' functional area variables.

c. Regression Significance

After fitting the data to the second model, all of the functional area variables reflected increased R^2 statistics. The remaining functional area variables (OPER, SUPP) were dropped from further analysis.

TABLE B-3. MODEL 2 REGRESSION COEFFICIENTS

VARIABLE	a-hat	b_1-hat	b_2-hat	c_i-hat
PIER (i=1)	1.46E5	-202.83	0.05	7.57E5
OPER (i=1)	22163.94	683.22	0.00	14238.95
SUPP (i=1)	-5.62E5	240.12	0.12	7.14E5
TROOP(i=1)	1.43E6	-4183.15	0.03	-2.03E5
PAVE (i=1)	-5.61E4	366.11	-0.07	3.01E5
GRNDS(i=1)	2.79E5	13.53	0.02	-2.06E5

i= 1= status quo

Table B-4 presents the R^2 statistic; the regression significance, p; and the t statistic with its significance level, r; for those functional area variables which had significant results for Model 2.

TABLE B-4. REGRESSION STATISTICS AND SIGNIFICANCE LEVELS

VARIABLE	R^2	p	t	r
PIER	0.84	0.04	1.431	0.23
TROOP	0.73	0.13	-0.394	0.71
PAVE	0.77	0.09	1.059	0.35
GRNDS	0.99	0.00	-2.789	0.05

d. Effects of Contracting Alternatives

Only GRNDS reflected any significant impact of contracting. In this case, the status quo was significantly better in performance (p=.05) than the BOS alternative. For the remaining functional area variables, BOS contracts did not result in any significant change over the status quo.

(1) The GRNDS Data. For SUBASE Bangor, the number of acres covered under the GRNDS function increased dramatically during the last year of the study. By comparison, SUBASE San Diego reported less than 6% of the area of SUBASE Bangor. Although Bangor's costs decreased slightly during the four-year period, San Diego's costs were still only 26% those of Bangor.

It is believed that San Diego's status quo methods were more efficient than Bangor's BOS contract for two reasons. One reason was the smaller work area covered by San Diego. The second reason was the dramatic increase in work performed at Bangor in 1987, which caused San Diego's data to appear more stable and more resistant to the effects of outlier observations.

APPENDIX C. NAVAL STATIONS RESULTS

Using the procedures described in Chapter III of this thesis, the following results were obtained for the Naval Stations base set.

A. NAVAL STATIONS' FUNCTIONAL AREA VARIABLES

The two Naval Stations selected for this thesis were NAVSTA Roosevelt Roads and NAVSTA Diego Garcia. Each is a primary support base for forward deployed surface units. Sixteen functional areas variables were considered for these bases. A description of the sixteen functional area variables is provided in Figure C-1.

Of these sixteen functional area variables, all had known contracting histories, as NAVSTA Diego Garcia was under a full-base BOS contract. NAVSTA Roosevelt Roads performed these functions under in-house or selected function contracts.

B. MODEL RESULTS

1. Model 1

The first simple regression model was applied to the sixteen Naval Station base set functional area variables.

DESCRIPTION OF FUNCTIONAL AREA VARIABLES

AVNB -- aviation operations buildings (thousands of square feet)

RUN -- airfield runways and other airfield pavements (thousands of square yards)

UTILS -- electricity, water and sewage (thousands of linear feet)

STOR -- supply storage (thousands of square feet)

PAVE -- roads and streets, other surfaced areas, sidewalks (thousands of square yards)

GRND -- improved and semi-improved grounds (acres)

EMERG -- total building area, representative of amount of emergency service work performed on real property (thousands of square feet)

OPER -- buildings related to operational functions, including communications, land operations, maintenance and production (thousands of square feet)

SUPP -- medical and administrative buildings (thousands of square feet)

TROOP -- BEQs/BOQs and galley facilities (thousands of square feet)

OTHFAC-- navigation and traffic aids, waterfront buildings and facilities (per each item)

PIER -- piers (thousands of square yards)

PERIM -- drainage facilities, fences, walls and gates (thousands of linear feet)

COMN -- community buildings, MWR facilities (thousands of square feet)

CLEAN -- total building area, representative of pest management and contracted custodial services (thousands of square feet)

TRASH -- garbage disposal (thousands of cubic yards)

Figure C-1. Description of Submarine Bases Functional area variables

a. Regression Significance

Table C-1 provides the R^2 statistics for the combined bases. The table explicitly identifies those regressions which reflect dependence at a level of significance of p<=0.10.

TABLE C-1. R^2 STATISTICS AND SIGNIFICANCE LEVELS

VARIABLE	R SQ.	SIG. LEVEL(p)
AVNB	0.61	0.02
GRND	0.73	0.01
OTHFAC	0.52	0.04
PIER	0.79	0.003
PERIM	0.63	0.02
CLEAN	0.90	0.00

b. Residual Analysis

The sixteen component-residual plots showed the data clustered by base. As was concluded in Chapter III, this indicated that the regressions were not only dependent on the work and cost data, but also on the bases for which the data were obtained.

c. Tests For Anticipated Modeling Concerns

(1) Data Inconsistencies. Data entries were estimated for 7 missing data points (5% of all data points). Those functional area variables for which data points were estimated were checked for artificially high significance. The Naval Station base set included estimated data for four functional area variables, three of which were significant. This may indicate a possible relationship between data estimation and regression significance.

(2) Autocorrelation. The functional area variables for the combined bases were also tested for autocorrelation by computing their Durbin-Watson (D-W) statistics. With 32 observations, 2 degrees of freedom, and 1% significance, the values for d_l and d_u were 1.100 and 1.352, respectively. D-W statistics yielded values for four functional area variables were less than d_l and greater than zero, indicating autocorrelation. After transforming this data, the autocorrelation was resolved. Of the other twelve functional area variables, nine statistics did not show autocorrelation; while three statistics fell within the inconclusive region.

(3) Heteroscedasticity. The clustering of data by base and the overall spread of observations did not indicate that heteroscedasticity was likely; therefore, no formal tests were performed.

(4) Multicollinearity. Multicollinearity was absent from the sixteen Naval Station functional area variables.

(5) Test For Structural Change. When the Chow test was applied to the Naval Station base set, the F(.05) table value was 3.34 for 2 and 28 degrees of freedom. The calculated values for five functional area variables fell below this table value, indicating no structural change. For the remaining eleven functional area variables, the calculated values were greater than the table value, indicating structural change. This may have been due to the large number of degrees of freedom (28) used.

(6) Summation of Modeling Tests. Table C-2 summarizes the results obtained from the hypothesis tests discussed in sections (2) and (5) above.

2. Model 2

a. Data Considerations

For the sixteen Naval Station functional area variables, all had known contracting histories, due to Diego Garcia's BOS contract. NAVSTA Roosevelt Roads used the in-house contracting alternative for three of the sixteen functional area variables and selected function contracts for the remaining thirteen.

TABLE C-2. SUMMATION OF MODELING TESTS

VARIABLE	TESTS	
	AUTOCORRELATION	STRUCTURAL CHANGE
AVNB	Inconclusive	Accept Ho
RUN	Accept Ho	Reject Ho
UTILS	Reject Ho	Accept Ho
STOR	Accept Ho	Reject Ho
PAVE	Reject Ho	Reject Ho
GRND	Accept Ho	Reject Ho
EMERG	Accept Ho	Reject Ho
OPER	Reject Ho	Accept Ho
SUPP	Accept Ho	Reject Ho
TROOP	Accept Ho	Reject Ho
OTHFAC	Accept Ho	Reject Ho
PIER	Inconclusive	Accept Ho
PERIM	Accept Ho	Reject Ho
COMN	Reject Ho	Reject Ho
CLEAN	Accept Ho	Reject Ho
TRASH	Inconclusive	Accept Ho

b. **Application of Model 2**

Table C-3 presents the estimated coefficients for Model 2 for the Naval Stations' functional area variables.

c. **Regression Significance**

All of the R^2 statistics increased after the second model was applied to the data, however half were not significant and were dropped from the analysis. Table C-4 presents the R^2 statistic; the regression significance, p; and the t statistic with its significance level, r; for those functional area variables which had significant results for Model 2.

d. Effects of Contracting Alternatives

GRND and UTILS had been won as in-house contracts by Roosevelt Roads and were under BOS contract at Diego Garcia. Both functional area variables showed increased costs under the in-house alternative.

For the remaining six functional area variables, the BOS contract was found to be more efficient for only one, PERIM, but not significantly. For the remaining five functional area variables, the selected function contracts were insignificantly less costly than the BOS contract. Of these five, CLEAN was the most nearly significant (p=.19).

TABLE C-3. MODEL 2 REGRESSION COEFFICIENTS

VARIABLE	a-hat	b_1-hat	b_2-hat	c_i-hat
GRND (i=2)	1.58E8	-1.17E5	-0.12	3.60E9
UTILS (i=2)	4.34E5	-259.30	0.99	2.01E5
STOR (i=2)	-6.85E4	705.99	0.00	-8.03E4
AVNB (i=3)	55870.75	-678.51	0.00	7721.38
RUN (i=3)	8388.31	32.18	0.00	32701.39
PAVE (i=3)	-8.71E5	255.84	0.15	-5.00E5
EMERG (i=3)	4.56E5	144.94	-0.04	-5.95E5
OPER (i=3)	-8.45E5	737.82	0.14	-2.51E5
SUPP (i=3)	1.95E5	-2468.09	0.00	9.01E5
TROOP (i=3)	-2.00E5	70.31	0.10	-1.02E5
OTHFAC(i=3)	78031.72	-3003.56	0.02	-670.34
PIER (i=3	-1.30E5	5941.54	0.02	-3.05E4
PERIM (i=3)	31824.48	-26.04	0.00	53587.63
COMN (i=3)	-2.45E6	1692.72	0.12	-6.29E5
CLEAN (i=3)	3.48E5	99.01	-0.01	-7.20E5
TRASH (i=3)	13256.63	2.22E5	-221.93	31188.34

i= 2= in-house contract
3= selected function contract

TABLE C-4. REGRESSION STATISTICS AND SIGNIFICANCE LEVELS

VARIABLE	R^2	p	t	r
GRND	0.92	0.01	2.086	0.11
UTILS	0.95	0.004	0.228	0.83
PAVE	0.79	0.08	-0.277	0.80
OPER	0.79	0.07	-0.713	0.52
OTHFAC	0.88	0.03	-0.046	0.97
PIER	0.84	0.04	-0.425	0.69
PERIM	0.83	0.05	1.249	0.28
CLEAN	0.96	0.03	-1.579	0.19

The greater efficiency of the selected function contract was believed to be due to the increase in both work and costs at Diego Garcia with a ratio of $0.30 per square foot, whereas Roosevelt Roads decreased output and gradually decreased prices to attain a work-to-cost ratio of $0.03 per square foot.

APPENDIX D. NAVAL AIR FACILITIES RESULTS

Using the procedures described in Chapter III of this thesis, the following results were obtained for the Naval Air Facilities base set.

A. NAVAL AIR FACILITIES' FUNCTIONAL AREA VARIABLES

The two Naval Air Facilities selected for this thesis were NAF Midway and NAF Atsugi. Each is a primary support base for forward-deployed carrier air wings and their staffs. Eleven functional areas variables were considered for these bases. A description of the eleven functional area variables is provided in Figure D-1.

Of these eleven functional area variables, all had known contracting histories, as NAF Midway was under a full-base BOS contract. NAF Atsugi used the status quo contracting alternative.

B. MODEL RESULTS

1. Model 1

The first simple regression model was applied to the eleven Naval Air Facility base set functional area variables.

DESCRIPTION OF VARIABLES

MAINT -- maintenance and production facilities (thousands of square feet)

STOR -- supply storage (thousands of square feet)

SUPP -- medical and administrative buildings (thousands of square feet)

TROOP -- BEQs/BOQs (thousands of square feet)

COMN -- community buildings (thousands of square feet)

UTILS -- electricity, steam and hot water (thousands of linear feet)

PAVE -- roads and streets (thousands of square yards)

GRND -- improved grounds (acres)

EMERG -- emergency service work performed on real property and other equipment (number of calls)

TRASH -- garbage disposal (thousands of cubic yards)

CLEAN -- contracted custodial services (thousands of square feet)

Figure D-1. Description of Submarine Bases Variables

a. Regression Significance

Table D-1 provides the R^2 statistics for the combined bases. The table explicitly identifies those regressions which reflect dependence at a level of significance of $p<=0.10$.

TABLE D-1. R^2 STATISTICS AND SIGNIFICANCE LEVELS

VARIABLE	R SQ.	SIG. LEVEL(p)
STOR	0.81	0.002
SUPP	0.53	0.04
TROOP	0.86	0.001
COMN	0.79	0.003
UTILS	0.58	0.03
GRND	0.72	0.008
TRASH	0.71	0.008
CLEAN	0.90	0.00

b. Residual Analysis

The eleven component-residual plots showed the data clustered by base. As was concluded in Chapter III, this indicated that the regressions were not only dependent on the work and cost data, but also on the bases for which the data were obtained.

c. Tests For Anticipated Modeling Concerns

(1) Data Inconsistencies. Data entries were estimated for 15 missing data points (8.5% of all data points). Those functional area variables for which data points were estimated were checked for artificially high significance. For the Naval Air Facility base set, six

variables included estimated data, although only three were significant.

(2) Autocorrelation. The functional area variables for the combined bases were also tested for autocorrelation by computing their Durbin-Watson (D-W) statistics. With 22 observations, 2 degrees of freedom, and 1% significance, the values for d_l and d_u were .914 and 1.284, respectively. Three variables (SUPP,PAVE,TRASH) yielded Durbin-Watson statistics less than d_l and greater than zero, therefore, autocorrelation was found to exist. After transforming the data, the autocorrelation was resolved. No autocorrelation was found for the remaining eight variables.

(3) Heteroscedasticity. The clustering of data by base and the overall spread of observations did not indicate that heteroscedasticity was likely; therefore, no formal tests were performed.

(4) Multicollinearity. Multicollinearity was absent from the eleven Naval Air Facility functional area variables.

(5) Test For Structural Change. When the Chow test was applied to the Naval Air Facility base set, the F(.05) table value was 3.55 for 2 and 18 degrees of freedom. The calculated values for two functional areas fell below this table value, indicating no structural change. For the

remaining nine variables, the calculated values were greater than the table value, indicating structural change.

(6) Summation of Modeling Tests. Table D-2 summarizes the results obtained from the hypothesis tests discussed in sections (2) and (5) above.

TABLE D-2. SUMMATION OF MODELING TESTS

VARIABLE	TESTS	
	AUTOCORRELATION	STRUCTURAL CHANGE
MAINT	Accept Ho	Accept Ho
STOR	Accept Ho	Accept Ho
SUPP	Reject Ho	Reject Ho
TROOP	Accept Ho	Reject Ho
COMN	Accept Ho	Reject Ho
UTILS	Accept Ho	Reject Ho
PAVE	Reject Ho	Reject Ho
GRND	Accept Ho	Reject Ho
EMERG	Accept Ho	Reject Ho
TRASH	Reject Ho	Reject Ho
CLEAN	Accept Ho	Reject Ho

2. Model 2

a. Data Considerations

For the eleven Naval Air Facility functional area variables, all had known contracting histories, due to Midway's BOS contract. NAF Atsugi used the status quo contracting alternative.

b. Application of Model 2

Table D-3 presents the estimated coefficients for Model 2 for the Naval Air Facilities' functional area variables.

c. Regression Significance

The second model yielded increased R^2 statistics for all eleven variables, although MAINT and EMERG were still insignificant. UTILS, which had been significant ($p=.03$) in the first model with an R^2 of .58 was not significant for the second model ($p=.25$). The variables MAINT, UTILS and EMERG were, therefore, omitted from the remainder of the analysis.

Of the eight remaining variables, PAVE increased in significance from an R^2 statistic of .01 in the first model to .98 ($p=.0005$) in the second model.

TABLE D-3. MODEL 2 REGRESSION COEFFICIENTS

VARIABLE		a-hat	b_1-hat	b_2-hat	c_i-hat
MAINT	(i=1)	1.44E5	-517.63	1.13	1.52E5
STOR	(i=1)	3202.87	142.11	0.05	-9820.04
SUPP	(i=1)	59870.22	315.07	-0.65	1.66E5
TROPP	(i=1)	-1.33E5	801.45	0.88	-1.54E5
COMN	(i=1)	-8.84E4	743.83	0.55	67958.24
UTILS	(i=1)	2.32E6	-3651.70	6.51	3.00E6
PAVE	(i=1)	-6.69E4	98.73	0.52	1.80E5
GRND	(i=1)	-4.71E4	512.43	0.55	-4.55E4
EMERG	(i=1)	-1.11E4	103.59	0.06	-1.13E6
TRASH	(i=1)	-4.30E4	2577.40	-0.20	88539.17
CLEAN	(i=1)	-5.16E4	1517.19	0.67	-2.59E5

i= 1= in-house

Table D-4 presents the R^2 statistic; the regression significance, p; and the t statistic with its significance level, r; for those functional area variables which had significant results for Model 2.

TABLE D-4. REGRESSION STATISTICS AND SIGNIFICANCE LEVELS

VARIABLE	R2	p	t	r
STOR	0.82	0.06	-0.269	0.80
SUPP	0.86	0.03	3.055	0.04
TROOP	0.93	0.01	-1.769	0.15
COMN	0.91	0.02	0.331	0.76
PAVE	0.98	0.001	3.592	0.02
GRND	0.95	0.01	-1.061	0.35
TRASH	0.89	0.02	1.538	0.20
CLEAN	0.95	0.01	-1.701	0.16

d. Effects of Contracting Alternatives

Four of the eight variables showed cost decreases with the use of BOS, although only two of these, SUPP and PAVE, were significant ($p<=.04$). The remaining four variables were only marginally more cost-efficient under the status quo contracting alternative.

For those variables indicating greater efficiency with BOS contracting, NAF Midway performed less work than NAF Atsugi. Midway's costs decreased for these variables, while Atsugi's costs increased. For example, for the variable SUPP, Midway spent an average of $0.35 per square foot compared with $0.60 at NAF Atsugi. For the variable

PAVE, Midway expended approximately $0.05 per square yard, while Atsugi's costs were a considerablely higher $0.65.

For those variables which reflected a marginal favoring of the status quo over BOS contracting, NAF Atsugi again saw ˜ crease in work for TROOP, but a decrease in output for CLEAN. Costs for these variables peaked, then decreased. In contrast, Midway again saw drastic reductions in the amount of work performed after 1984 and concomittant drops in costs incurred, although these began to increase in the last year.

Atsugi paid only slightly more per square foot of troop space ($0.63 versus $0.52), but was considerably more efficient in terms of custodial services ($0.93 versus $1.52). It is contended that because Atsugi increased its output while decreasing costs for the variable TROOP, it achieved a fairly significant advantage over Midway, which greatly decreased output but started to significantly increase costs toward the end of the period. Although not achieving a similarly significant work-to-cost ratio for CLEAN, Atsugi still displayed greater efficiency when compared with Midway's considerably higher work-to-cost ratio.

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